



Final Design of the Beam Source for the MITICA Injector

Diego Marcuzzi

Consorzio RFX

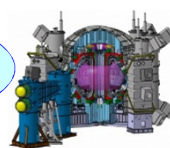


Consorzio RFX : what is it ?



Education program

Broader Approach
(JT60-SA)



Activities for DEMO

Other ITER/tokamak
activities

RFX experiment

ITER Neutral Beam
Test Facility

CONSORZIO RFX

(consortium of Padova University and
main Italian public research entities)

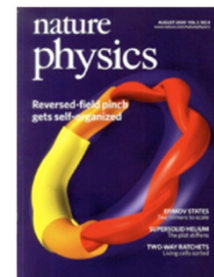
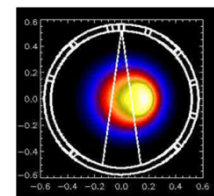
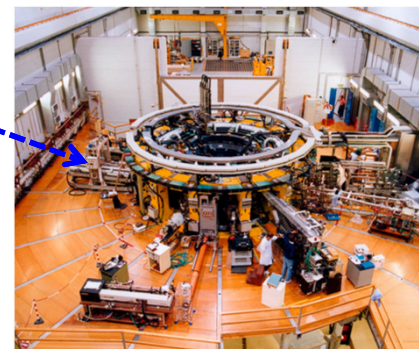
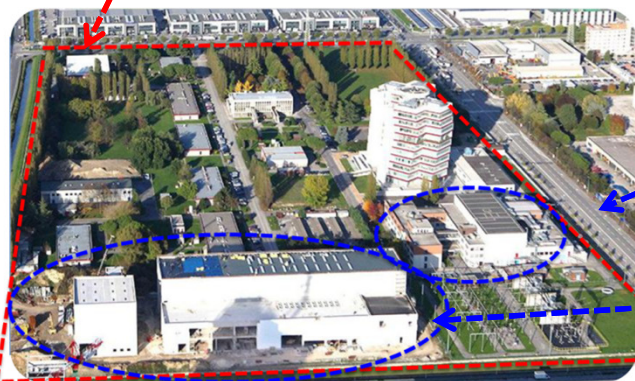
150 employees

(40 administration, 110 scientific)

~30 students

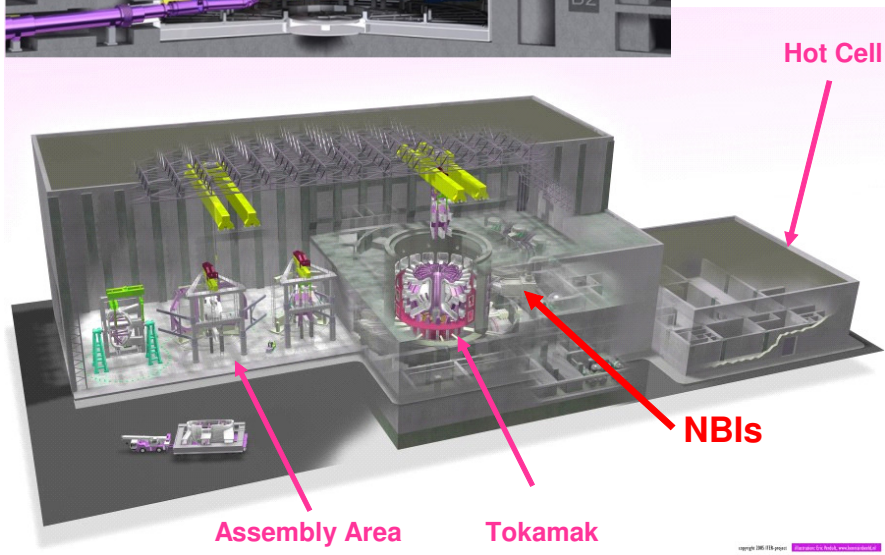
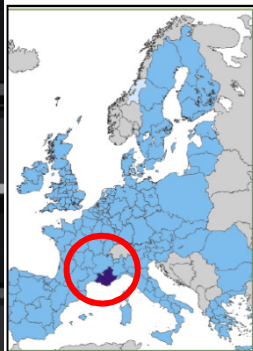
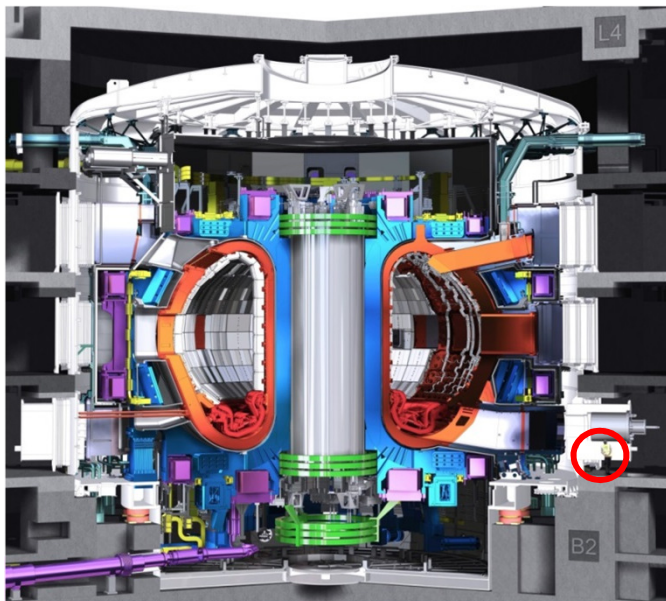
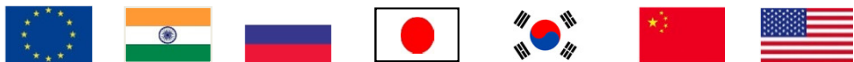
(degree & doctorate)

Consiglio Nazionale delle Ricerche
C.N.R. Padova Research Area



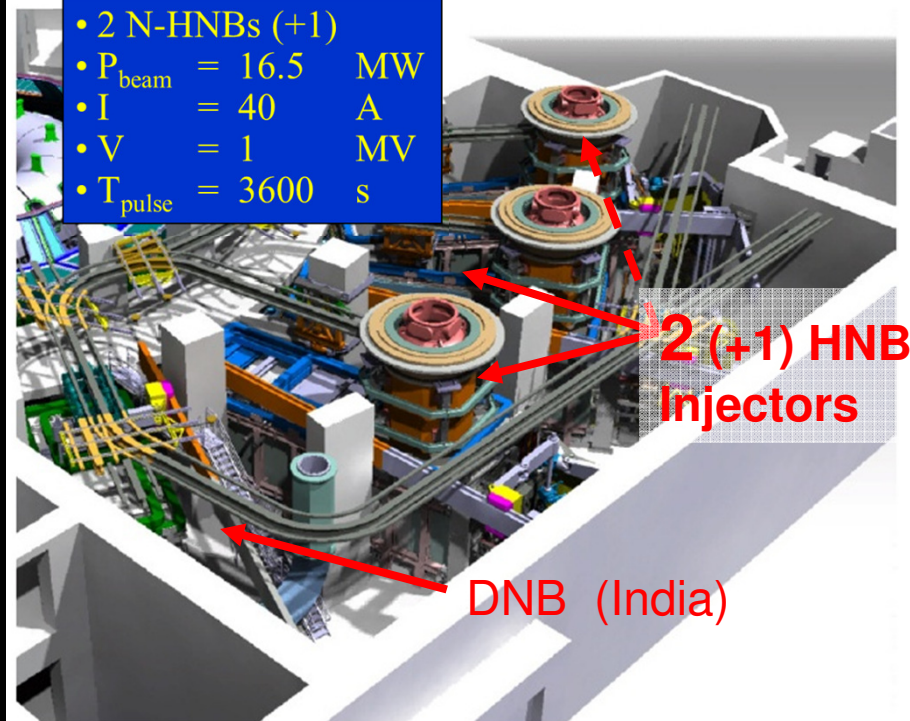


ITER & the Heating Neutral Beam System



Two HNB Injectors at 1 MV accelerating voltage and injecting 16.5 MW each into the plasma

- 2 N-HNBs (+1)
- $P_{\text{beam}} = 16.5$ MW
- $I = 40$ A
- $V = 1$ MV
- $T_{\text{pulse}} = 3600$ s



Large scientific/technological step from existing NB systems → Decision to establish a full scale Neutral Beam Test Facility (NBTF/PRIMA).

Agreements signed between IO and F4E (with the endorsement of Japan and India) and between F4E and Consorzio RFX

Strong international collaboration



Strong international cooperation for:

- Neutral Beam Test Facility
- ITER Heating NB
- ITER Diagnostic NB



CONSORZIO RFX
 Ricerca Formazione Innovazione



**Max-Planck-Institut
 für Plasmaphysik**
 EURATOM Association



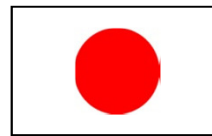
**UNIVERSITÉ
 PARIS-SUD 11**



**Istituto
 di Fisica del Plasma
 "Piero Caldirola"**
 Consiglio Nazionale delle Ricerche



IMIP ISTITUTO DI METODOLOGIE
 INORGANICHE E DEI PLASMI



प्लाज़्मा अनुसंधान संस्थान
Institute for Plasma Research



Moreover, ITALY is
 contributing with the NBTF
civil works and general
 services



ITER Neutral Beam Test Facility

Padova Research on Injector Megavolt Accelerated (PRIMA)

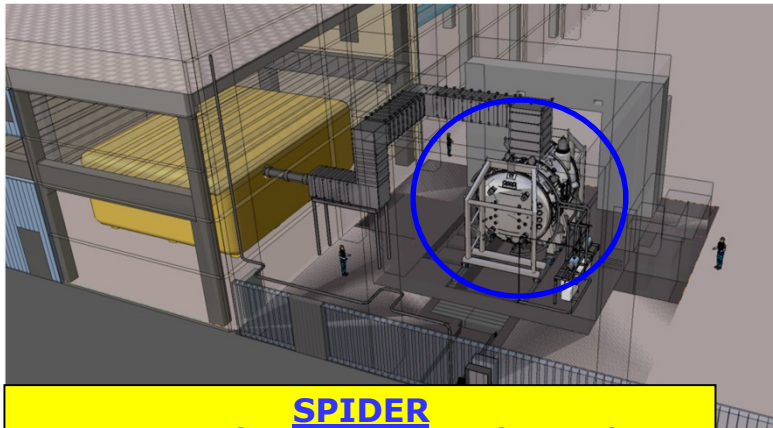


Neutron shield & assembly hall

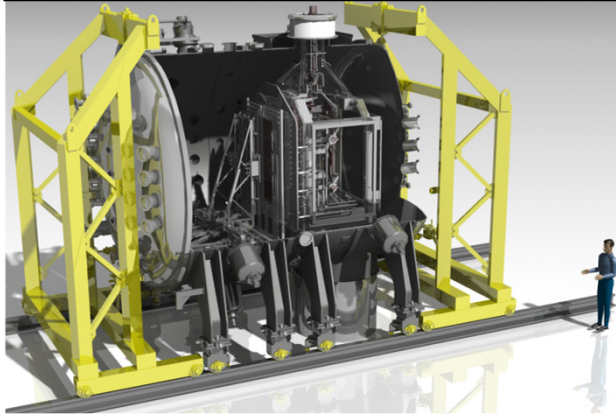


ITER Neutral Beam Test Facility

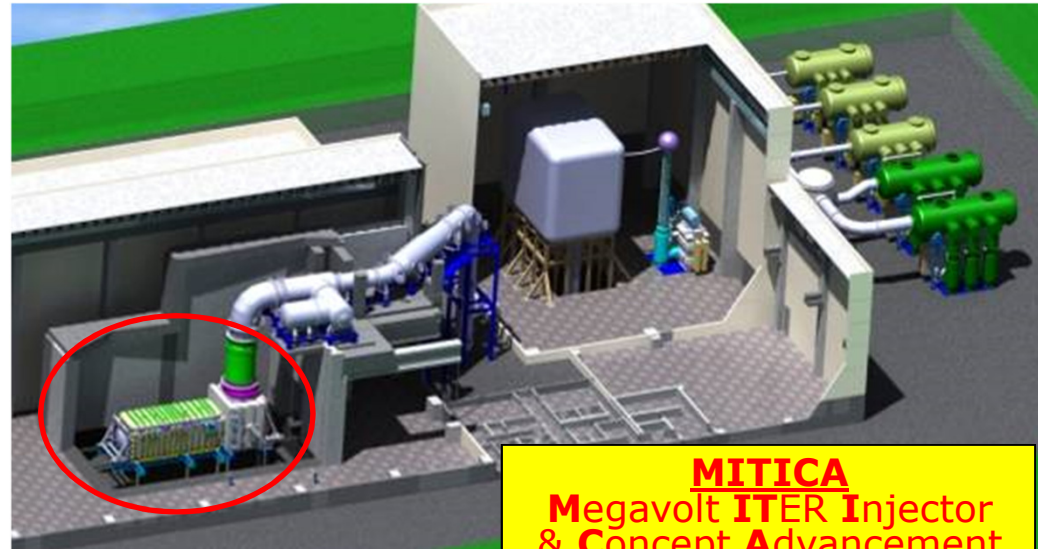
Padova Research on Injector Megavolt Accelerated (PRIMA)



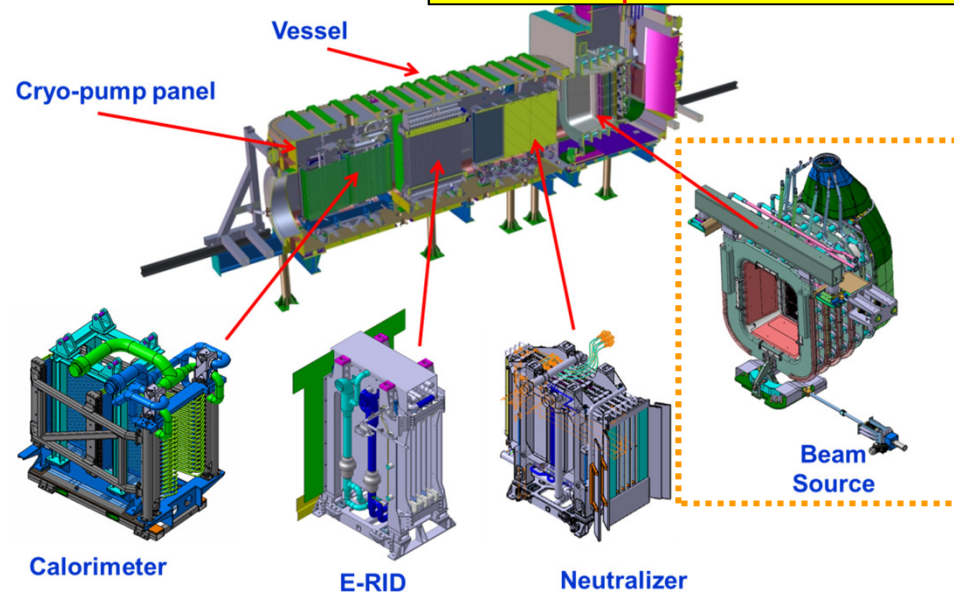
SPIDER
Source for Production of Ion of
Deuterium Extracted from Rf plasma



Two experiments are foreseen to be hosted in the PRIMA facility: an **ion source** prototype (DNB-relevant) and a **full injector** prototype



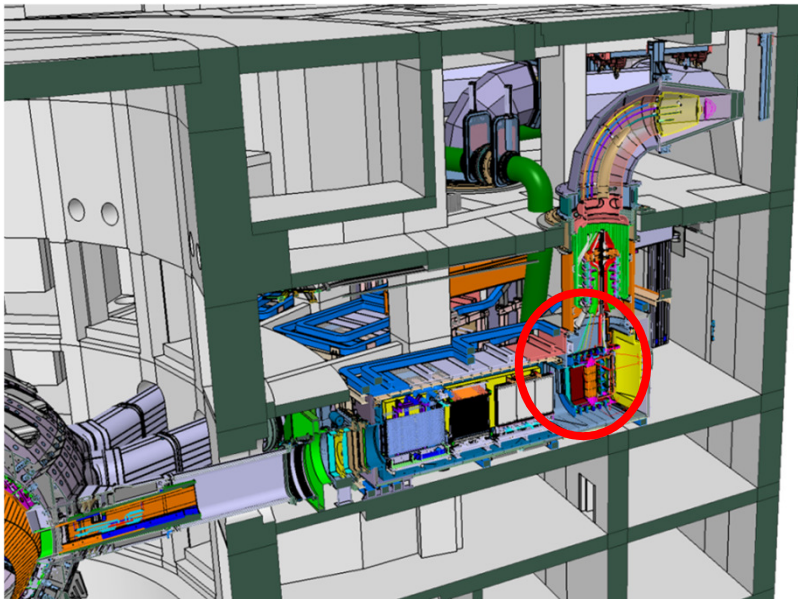
MITICA
Megavolt ITER Injector
& Concept Advancement





MITICA / HNB Beam Source - basics

ITER HNB

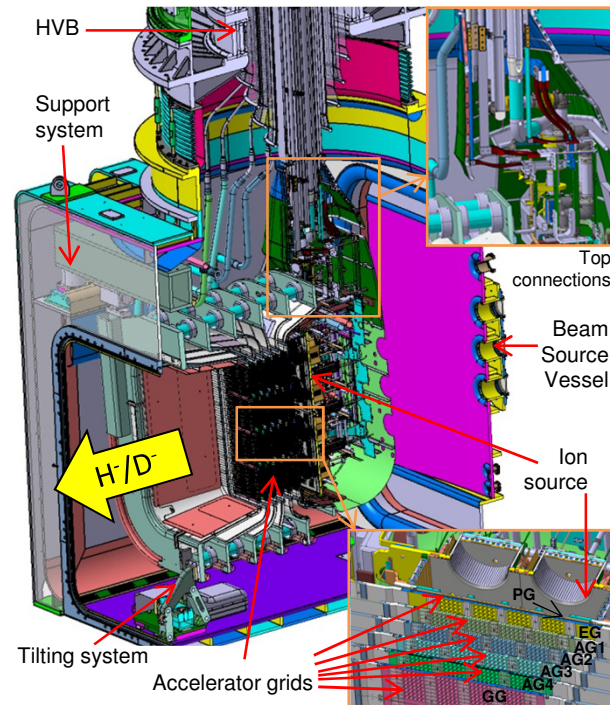


The **Beam Source** for the ITER Neutral Beam Injector...

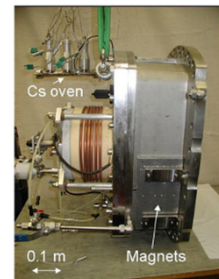
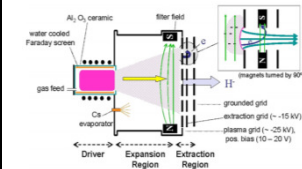
... designed (to be procured and tested first) for the **MITICA** experiment...

... based on the concept and experiments developed and running at **IPP** and **JAEA**

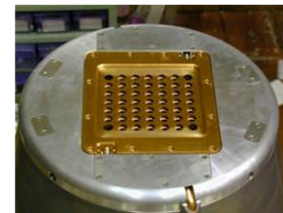
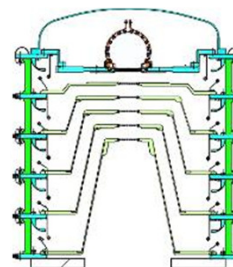
MITICA final design



IPP ion source concept and test beds



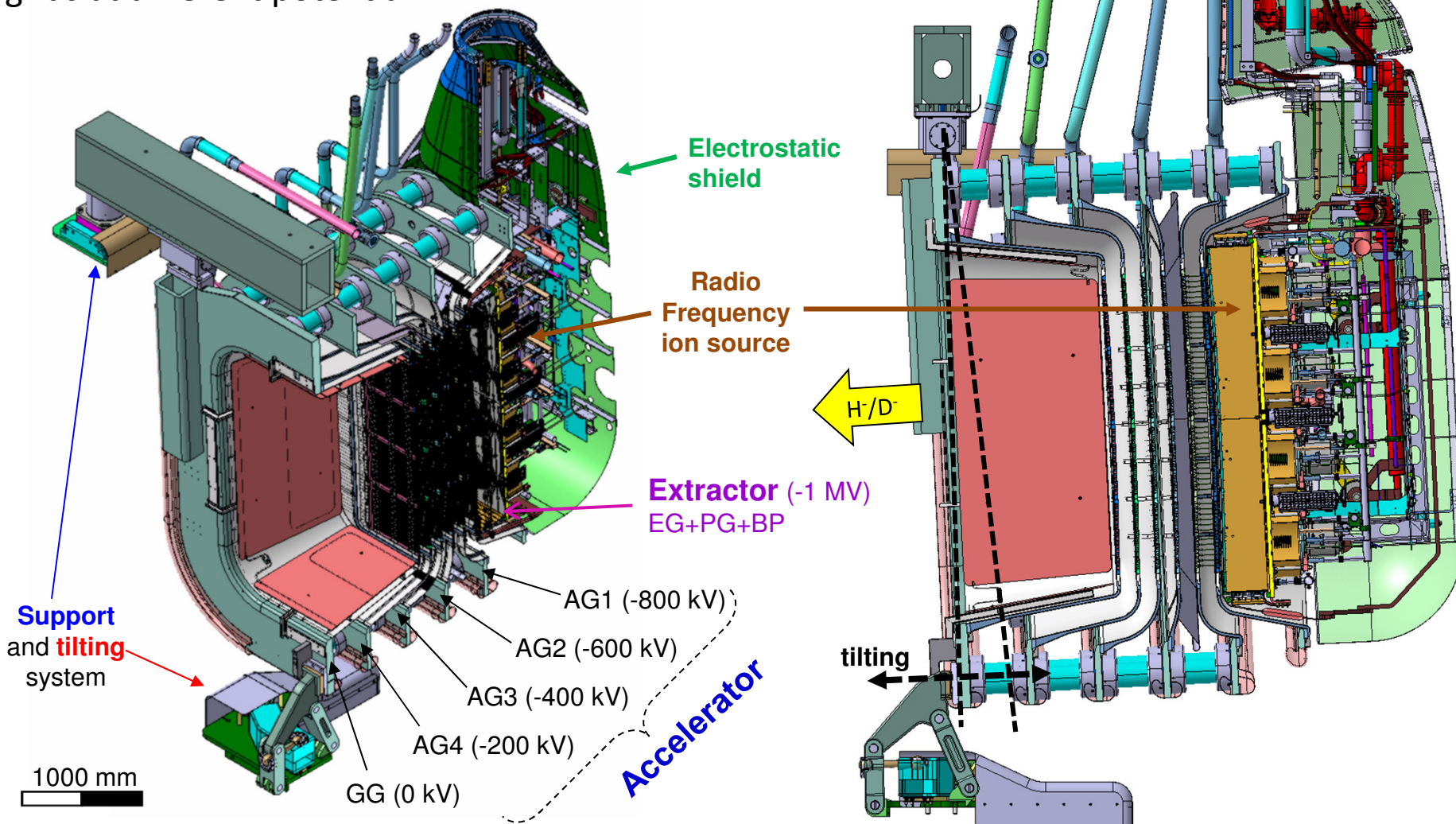
JAEA Megavolt Test Facility





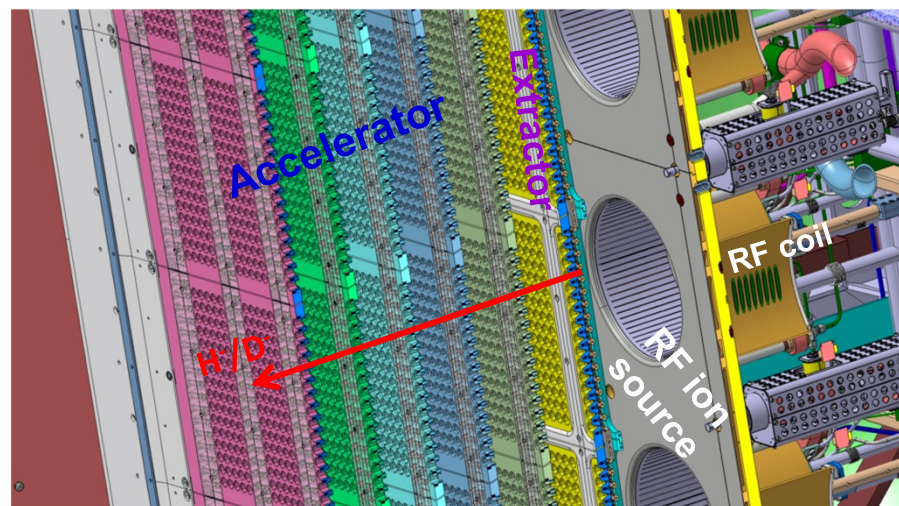
MITICA Beam Source - final design

Negative ions generated inside the RF ion source are extracted and accelerated by the electric field generated by the system of grids at different potential



MITICA Beam Source : the "core"

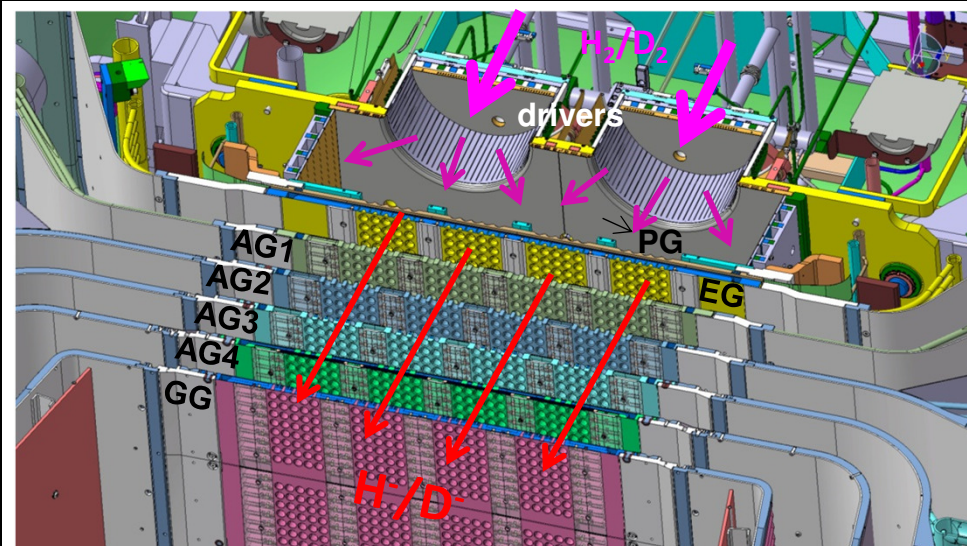
The functional "core"



Vertical section

H_2/D_2 gas is injected and ionized in each driver, then flows in the source main chamber.

Negative ions generated next to the Plasma Grid are extracted and then accelerated. Every grid has 4 segments, with 4 groups of 16×5 apertures, for a total of **1280 beamlets** of negative ions.



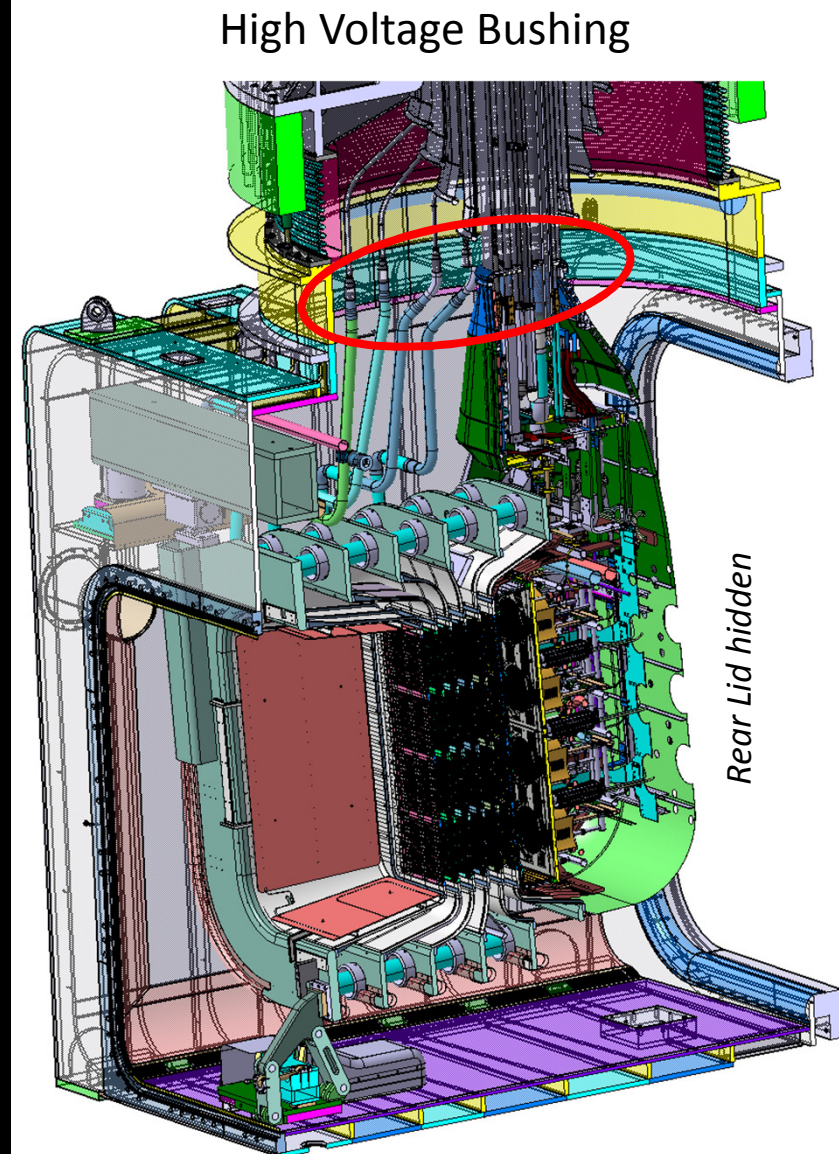
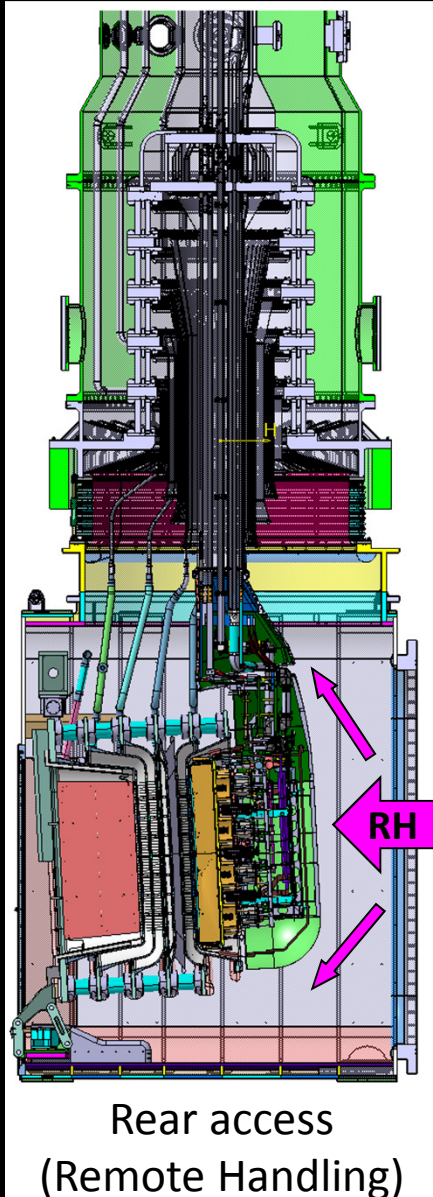
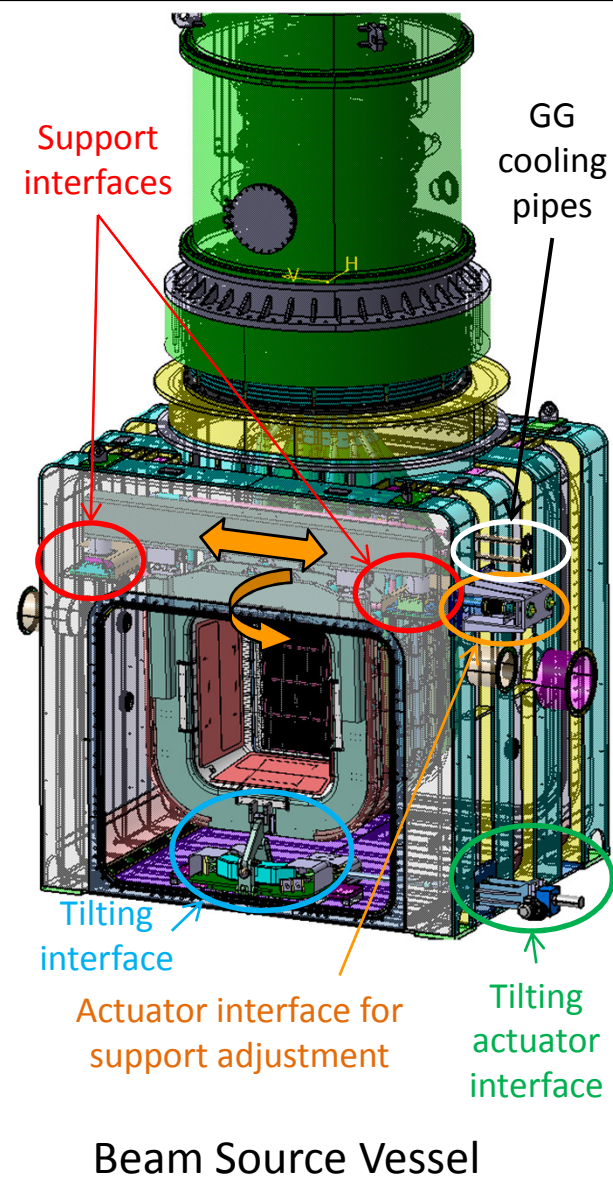
Horizontal section

In the next slides:

- Interfaces
- Grid design
- Accelerator ceramic insulator
- Accelerator assembly and alignment



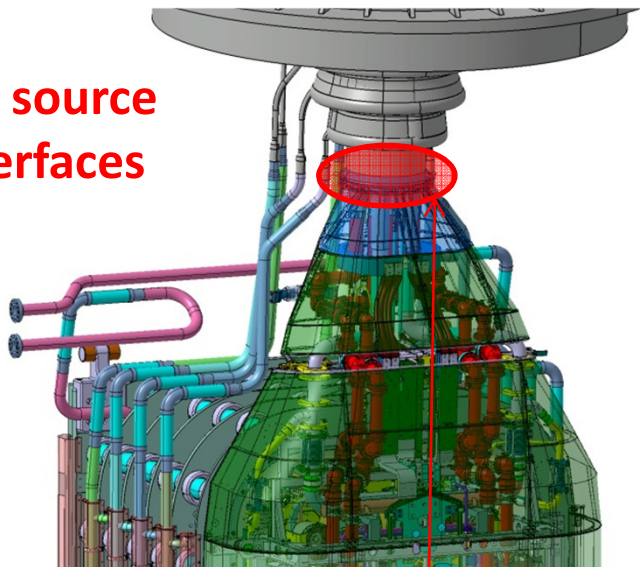
MITICA / HNB Beam Source - interfaces





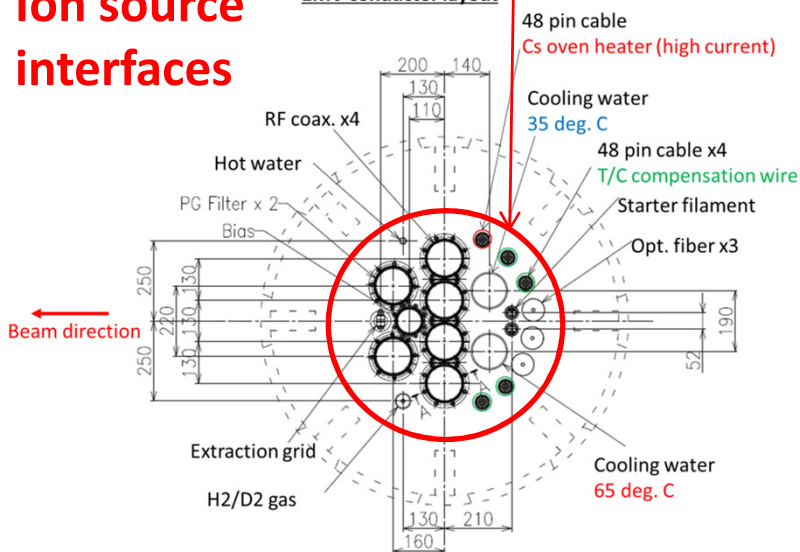
Beam Source / HV bushing interfaces

Ion source interfaces

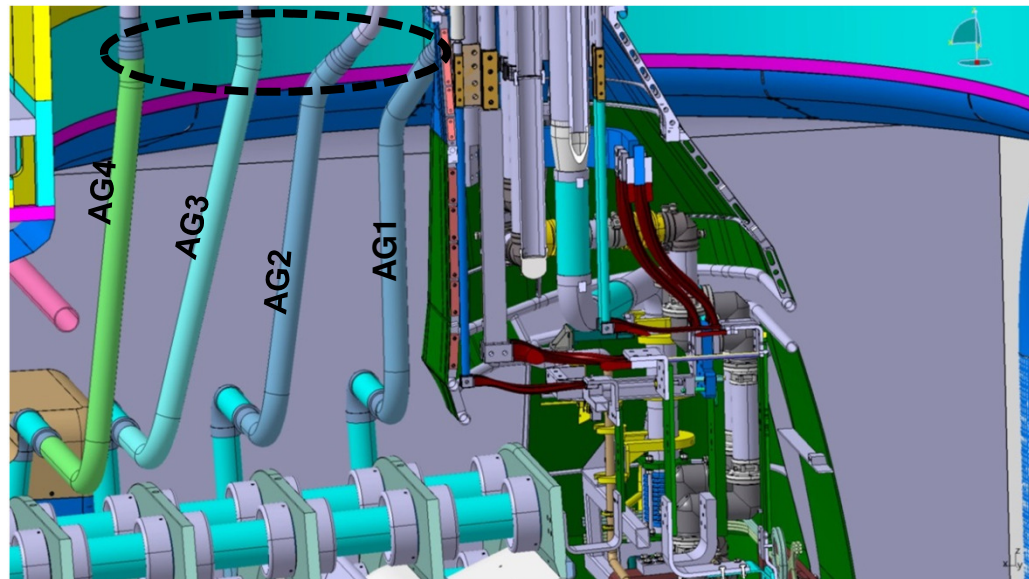


Ion source interfaces

1MV conductor layout



Accelerator interfaces – cooling pipes



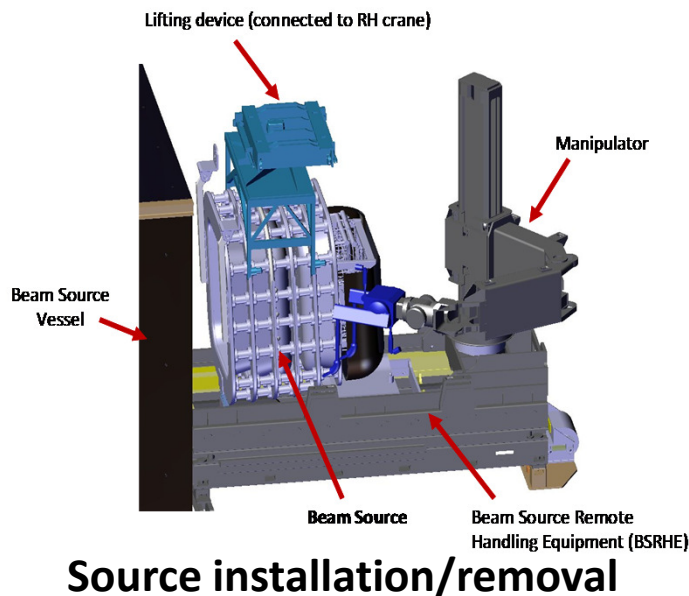
Around 20 **ion source interfaces** within the -1 MV shield have been finalized in all details:

- DC power supply
- RF coaxial lines
- Water supply
- Gas supply
- Signal cables
- Optical fibres

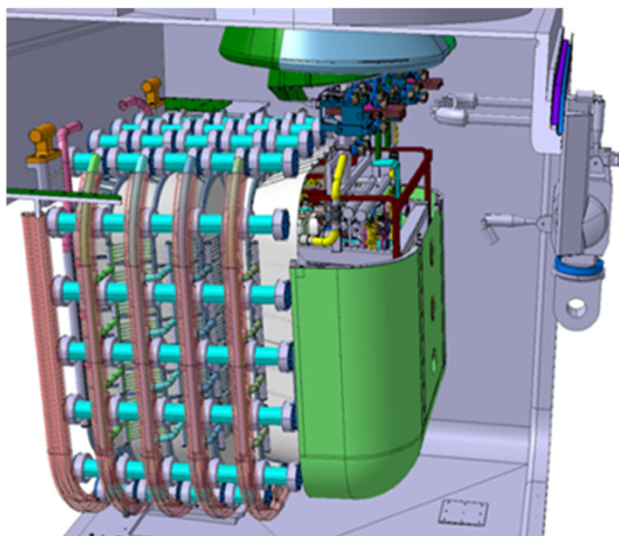
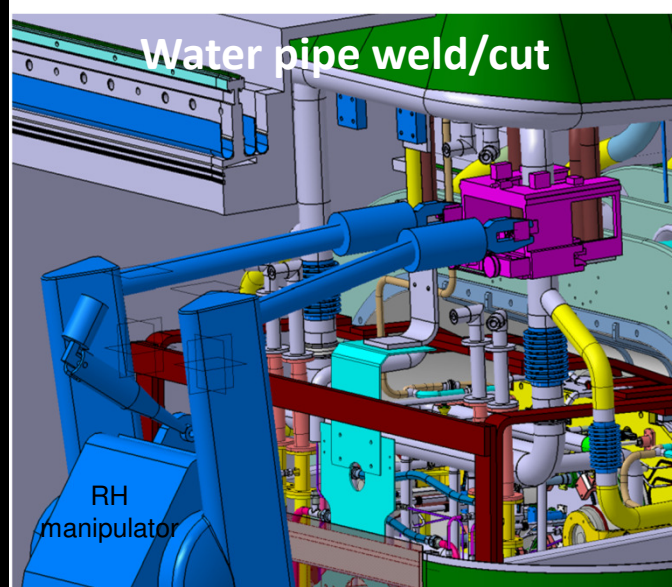
Design optimization of RF lines (ThuPE05)



Beam Source / RH Equipment interfaces



Maintenance interventions in ITER are typically remote handled for in-vessel components. The design takes into account related procedures, specifically developed

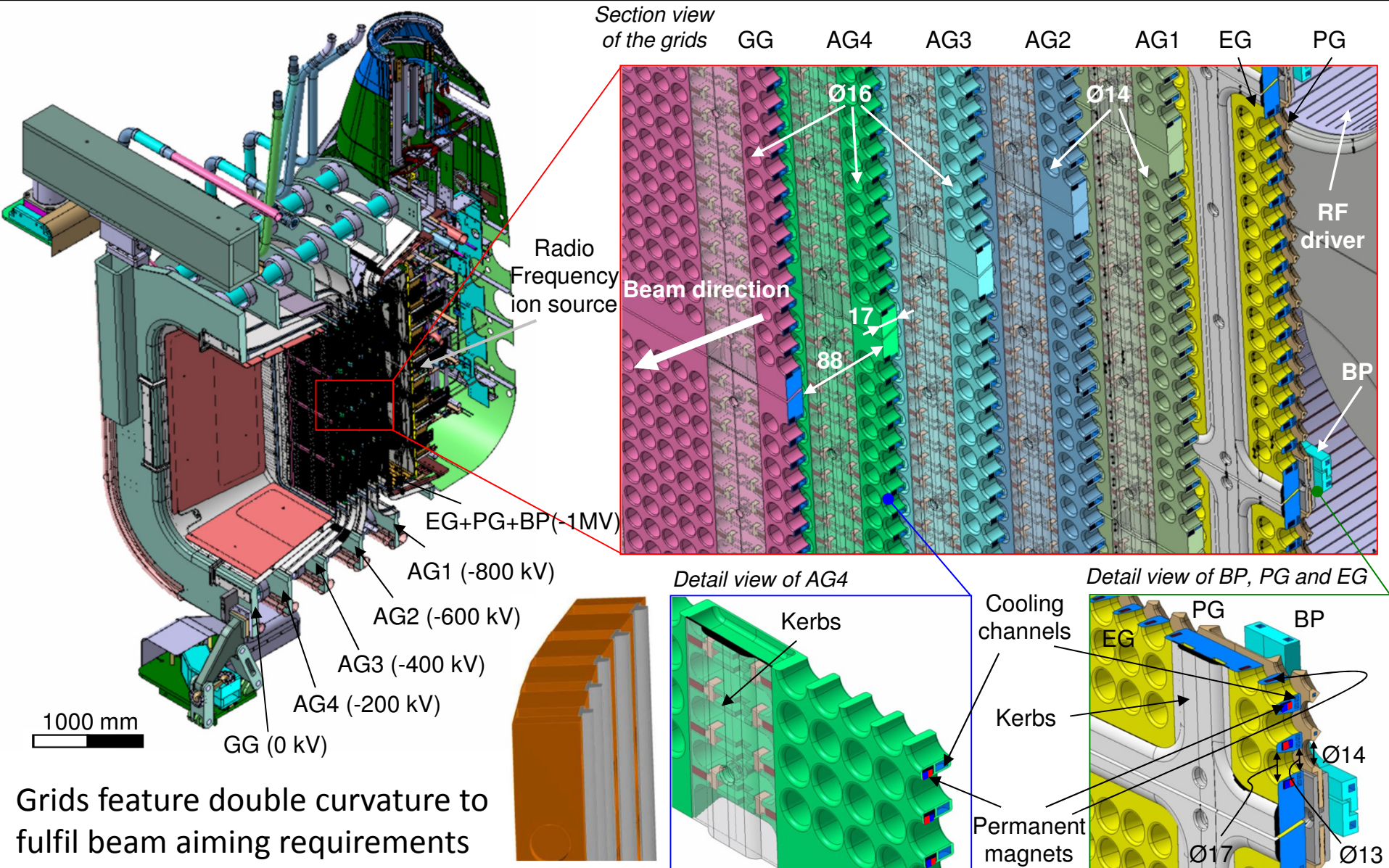


Example of maintenance intervention verification for the foreseen tasks



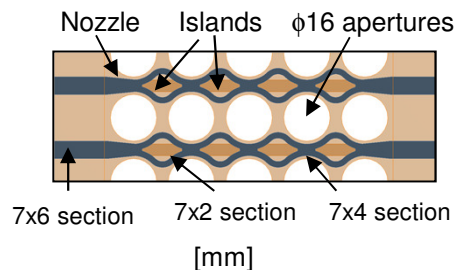
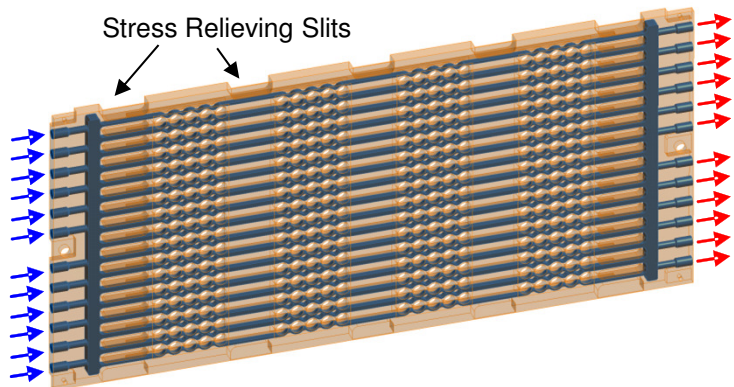


Accelerator final design

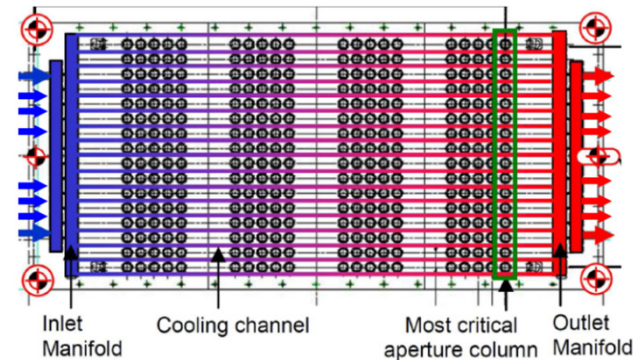




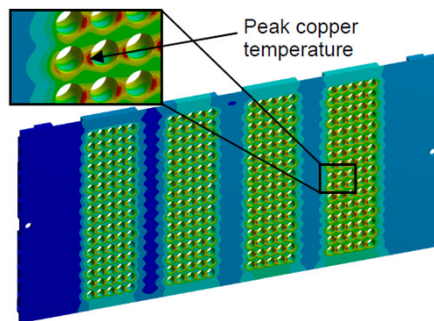
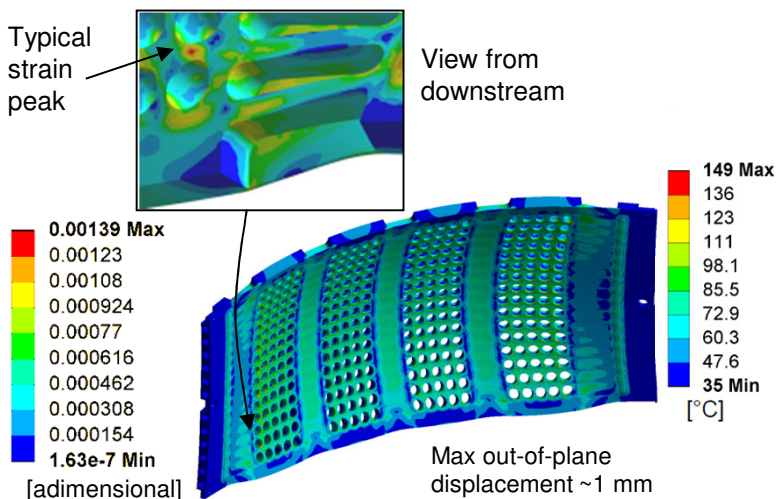
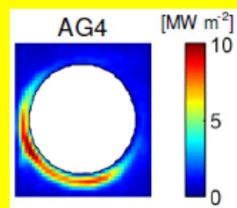
Grids final design



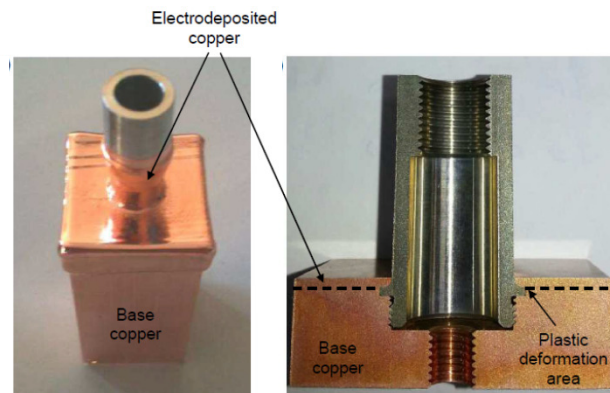
"Standard" design details and foreseen manufacturing cycle



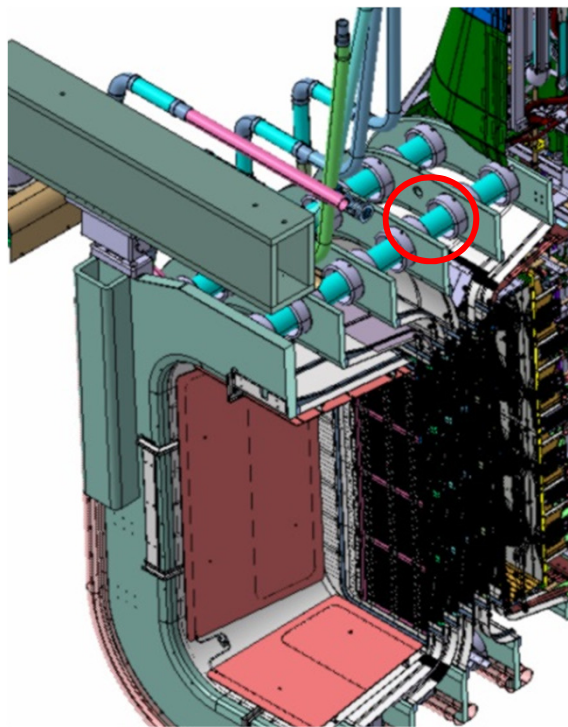
The power deposited on grids is very high and concentrated on the five acceleration grids, in the range $1.2 \div 1.6$ MW, with density up to 10 MW/m^2



Cu-AISI grid-pipe joint Vacuum Tight Threaded Junction (VTTJ), conceived and patented by Consorzio RFX



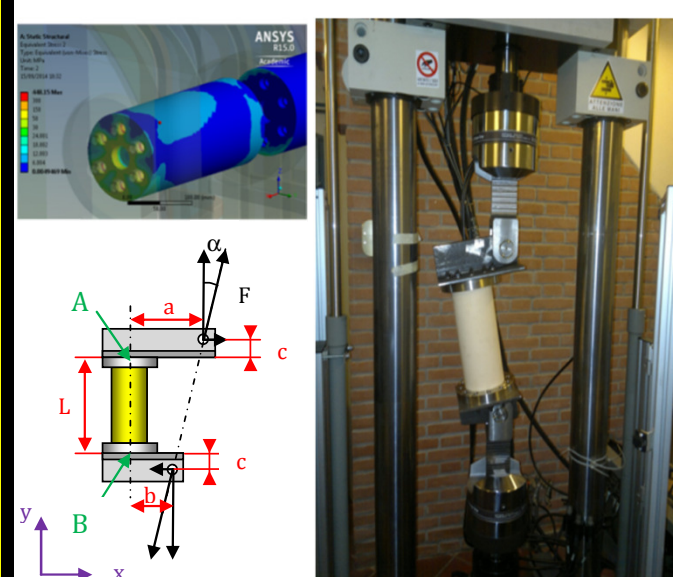
Accelerator ceramic insulators



5 groups of 18 ceramic insulators (Al_2O_3 , 99% purity) are part of the cantilevered accelerator structure.

The whole structure has been simulated to identify the most stressed insulators, in terms of tension, shear and bending forces.

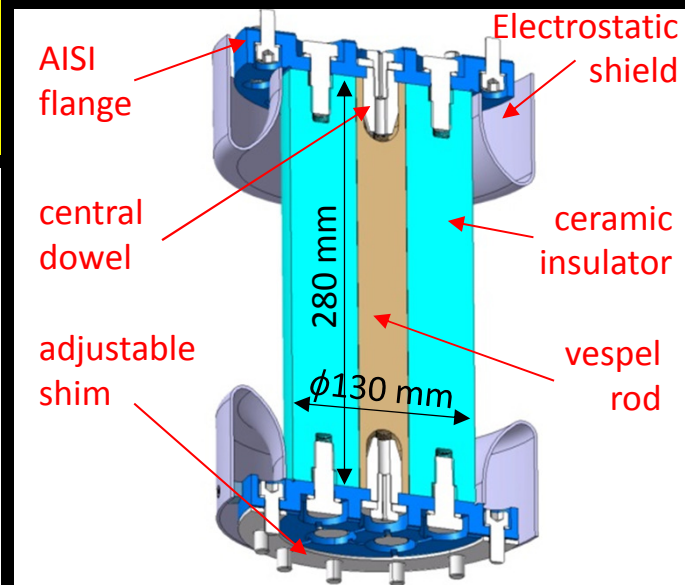
These data were “translated” in requirements for an equivalent tensile test.



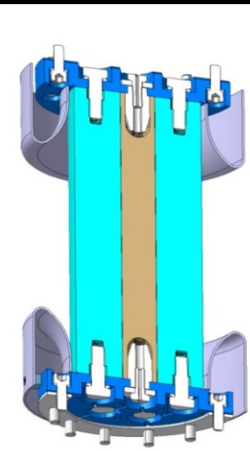
A full cylinder geometry had been first considered to maximize electrostatic performances.

Manufacture experienced difficulties in producing reliably components strong enough with such shape.

A hollow cylinder shape was then successfully produced, tested as foreseen and adopted as reference solution.

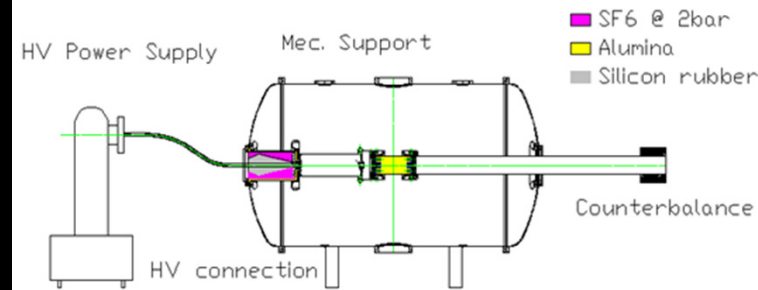


Accelerator ceramic insulators

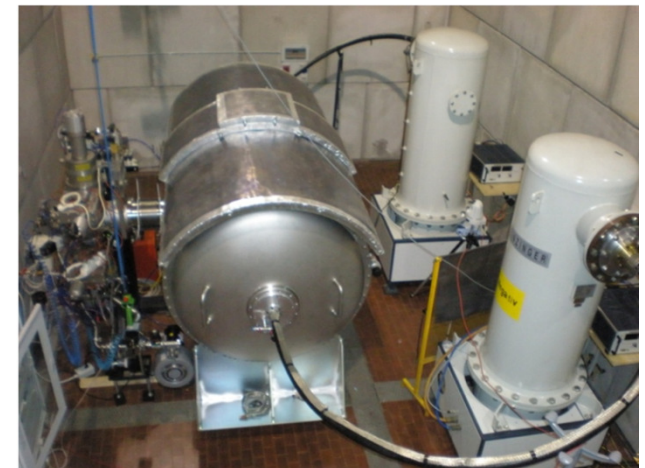
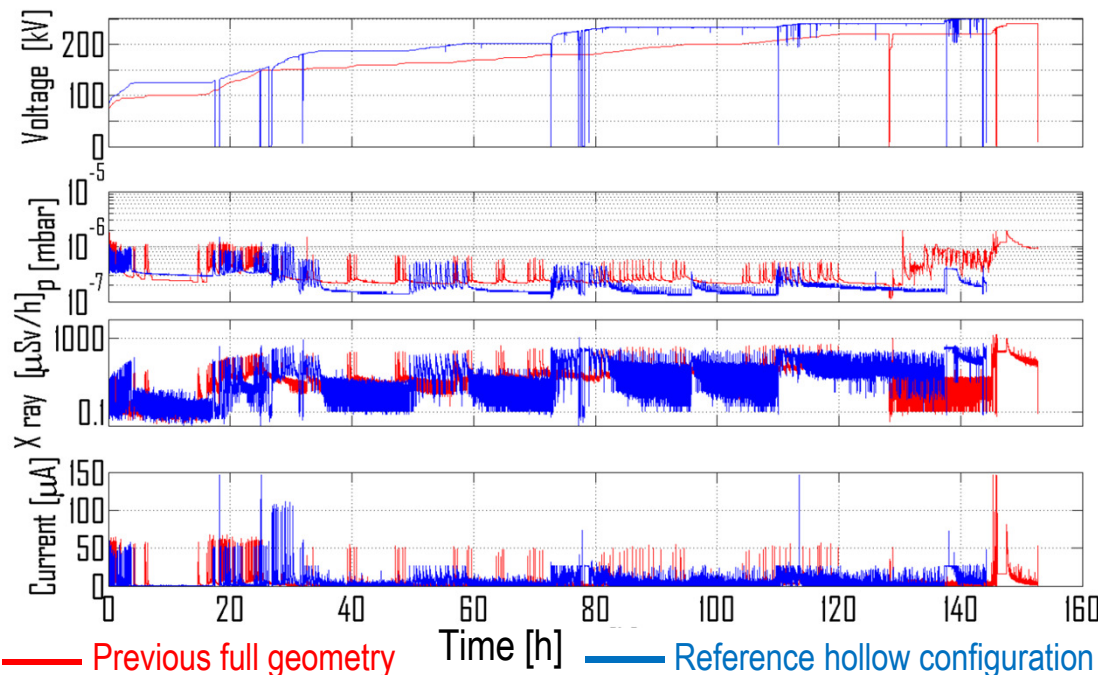


In order to withstand the electrical test at 240 kVdc in vacuum with a background pressure in the range $10^{-5} \div 5 \cdot 10^{-2}$ Pa, the central hole had to be filled with a vespel® rod, thermally shrink fitted to eliminate gaps.

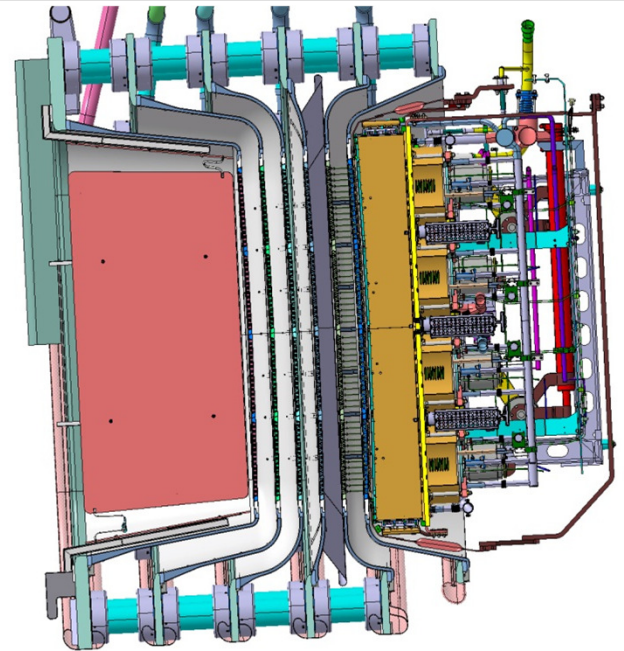
The required voltage was held for more than 20 h, with a leak current $< 50 \mu\text{A}$.



The electrical tests have been successfully carried out at the High Voltage Padova Test Facility @ Padova University

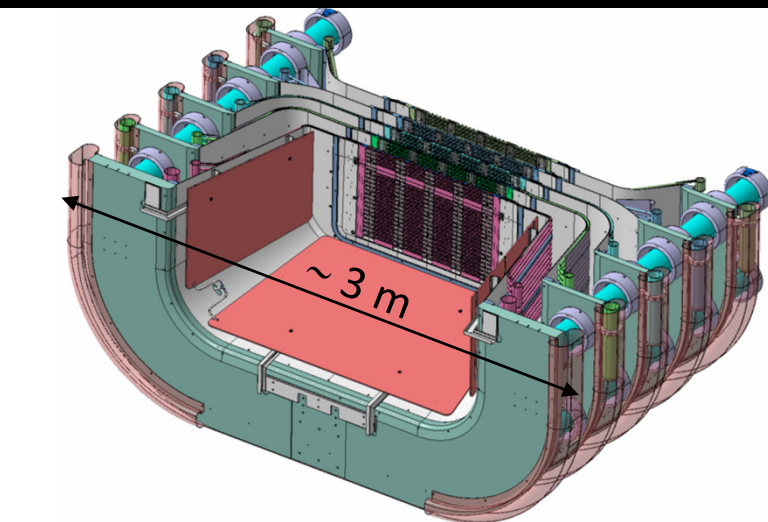


Assembly and alignment



The accelerator assembly and the alignment of corresponding apertures of different grid is one of the most challenging tasks.

- The system is very large and complex
- Many parts have difficult shape and manufacturing cycle
- Alignment requirements are very tight: maximum distance between corresponding aperture axes in the order of 0,2 mm in the extractor (between PG and EG) and 0,5 mm among AGs, at operation conditions. Offsets for each aperture were defined to deal with thermal deformation and physics requirements for optics.

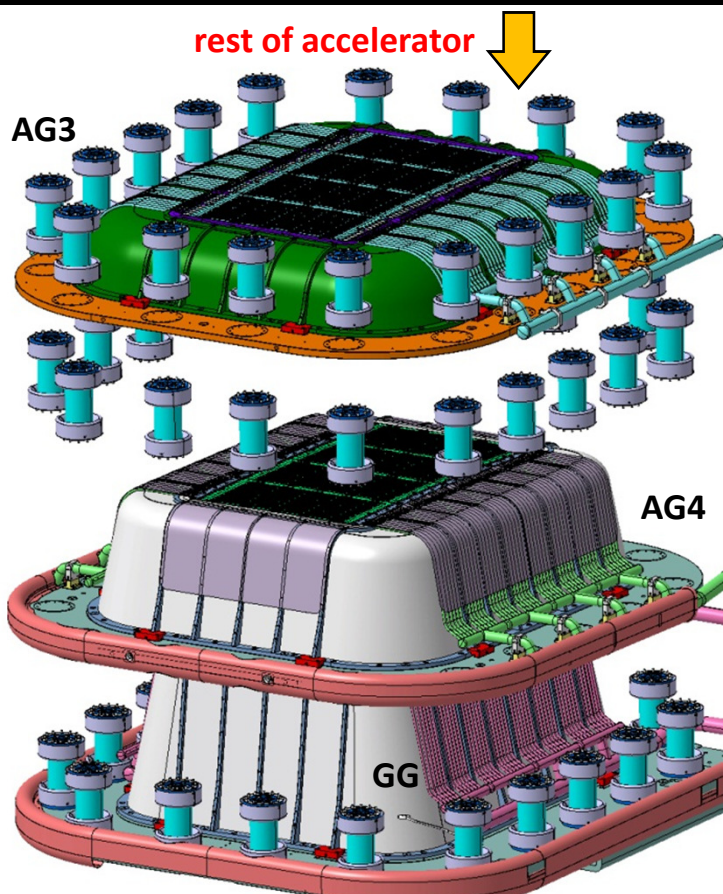


Grids must be aligned for proper beamlet optics, but also pointing in the right direction to reach ITER tokamak, hence each grid (segment, aperture) shall be correctly **positioned** in a unique absolute coordinate system.

Not only the position of apertures is important: the orientation of the grid surfaces influences the electric field distribution, hence beamlet optics.

Assembly and alignment

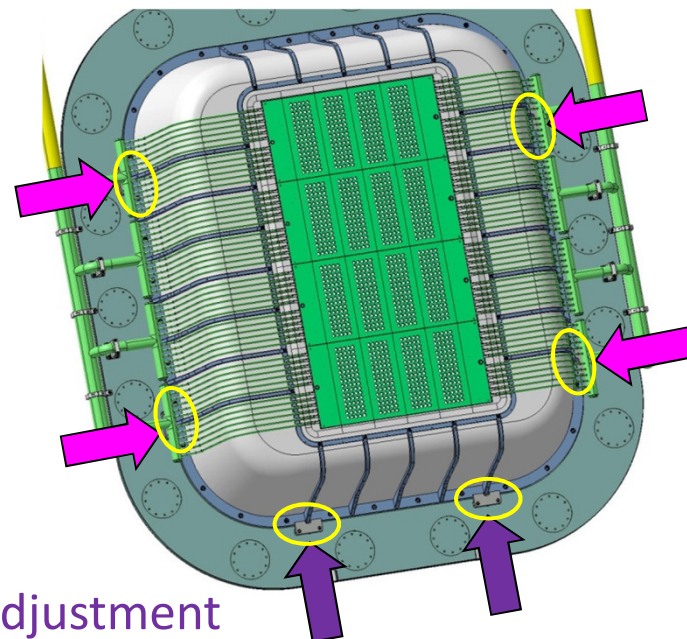
The accelerator will be assembled in progression starting from GG and going backwards, possibly at least initially with beam axis pointing downward for handling ease.



The source nominal configuration features the beam axis almost horizontal, cantilevered from the GG, hence gravity will likely affect the position of grids, that will need final vertical position check.

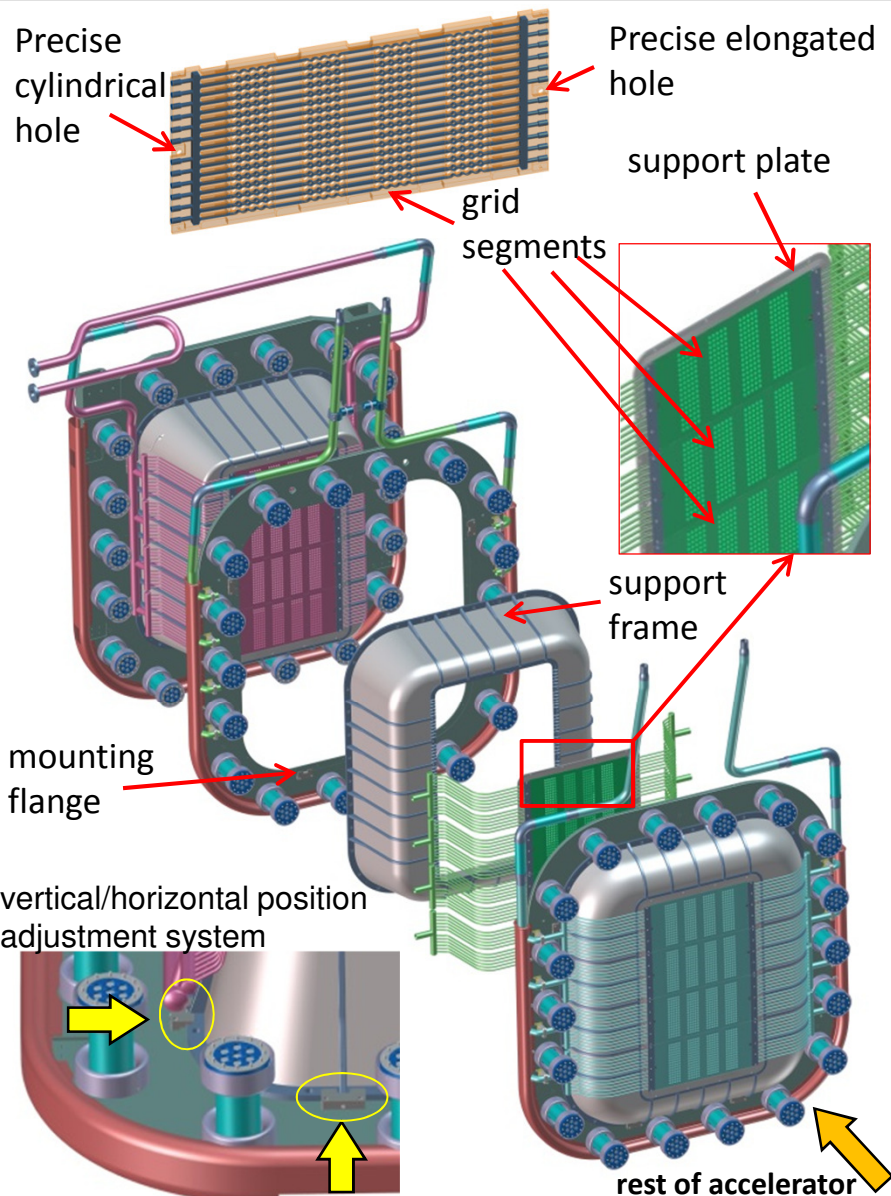
Due to the “nested” shape of the accelerator frames, at the completion of assembly grids are not in sight anymore.

Adjustment systems are foreseen on accelerator frames to regulate horizontal/vertical position of grids from outside.



Final Adjustment

Assembly and alignment



Criteria to handle the complex chain of tolerance in the accelerator (*and meet the goal!*):

- apertures will be precisely machined (in the order of few hundredths of mm tolerance) with respect to the reference holes for dowels in each grid segment
- two calibrated dowels lead the positioning of each grid segment onto the respective support plate
- once the link between each mounting flange and the adjacent one is carefully established (eighteen ceramic post-insulators), the position of grid+support frame can be adjusted in plane
- optical targets will be positioned on grid frames and segments, in order to allow the verification of the position of each grid at several stages throughout the assembly procedures



Thank you for your attention !

Monday Afternoon Poster Session – Empire (14:00-16:00)

MonPE01	Simulation of beam profiles from extracted ion current distributions for mini-STRIKE	P. Agostinetti
MonPE02	Multi-beamlet investigation of the deflection compensation methods of SPIDER beamlets	C. Baltador
MonPE07	Analysis of diagnostic calorimeter data by the transfer function technique	R.S. Delogu
MonPE22	Castellated tiles as the beam-facing components for the diagnostic calorimeter of the negative ion source SPIDER	S. Peruzzo
MonPE25	Gas Flow and Density Profile in NIO1 Accelerator and Vessel	E. Sartori
MonPE26	Simulation of Space Charge Compensation in a multibeamlet negative ion beam	E. Sartori
MonPE28	Numerical Simulations of the First Operational Conditions of the Negative Ion Test Facility SPIDER	G. Serianni

Tuesday Afternoon Poster Session – Empire (14:00-16:00)

TuePE28	Beam deflection applied to Neutral Beam Injection for a Fusion Devices reactor	N. Pisan
TuePE30	Characterization and Optimization of NIO1 Extraction Aperture by 3D PIC Model	N. Ippolito

Tuesday Afternoon Poster Session – Soho (14:00-16:00)

TuePS24	Preliminary Design of Electrostatic Sensors for MITICA Beam Line Components	S. Spagnolo
TuePS33	Particle Transport and Heat Loads in NIO1	P. Veltri
TuePS34	Optics of the NIFS Negative ion source test stand by infrared calorimetry and numerical modeling	P. Veltri

Posters by Consorzio RFX

Thursday Poster Session – Empire (14:00-16:00)

ThuPE01	First hydrogen operation of NIO1: characterization of the source plasma by means of an optical emission spectroscopy diagnostic	M. Barbisan
ThuPE02	Feasibility Study of a NBI Photoneutralizer Based on Nonlinear Gating Laser Recirculation	A. Fassina
ThuPE03	Off-normal and failure condition analysis of the MITICA negative-ion Accelerator	G. Chitarin
ThuPE05	Design optimization of RF lines in vacuum environment for the MITICA experiment	M. De Muri
ThuPE13	Development and tests of Molybdenum armed copper components for MITICA ion source	M. Pavei
ThuPE14	Simulation of diatomic gas-wall interaction and accommodation coefficients for Negative Ion Sources and accelerators	E. Sartori
ThuPE20	Transmission of electrons inside the cryogenic pumps of ITER Neutral Beam Injector	P. Veltri
ThuPE23	Steady state thermal-hydraulic analysis of the MITICA experiment cooling circuits	M. Zaupa / D. Marcuzzi
ThuPE25	Integration of RFQ Beam Coolers and Solenoidal Magnetic Field Traps	M. Cavenago